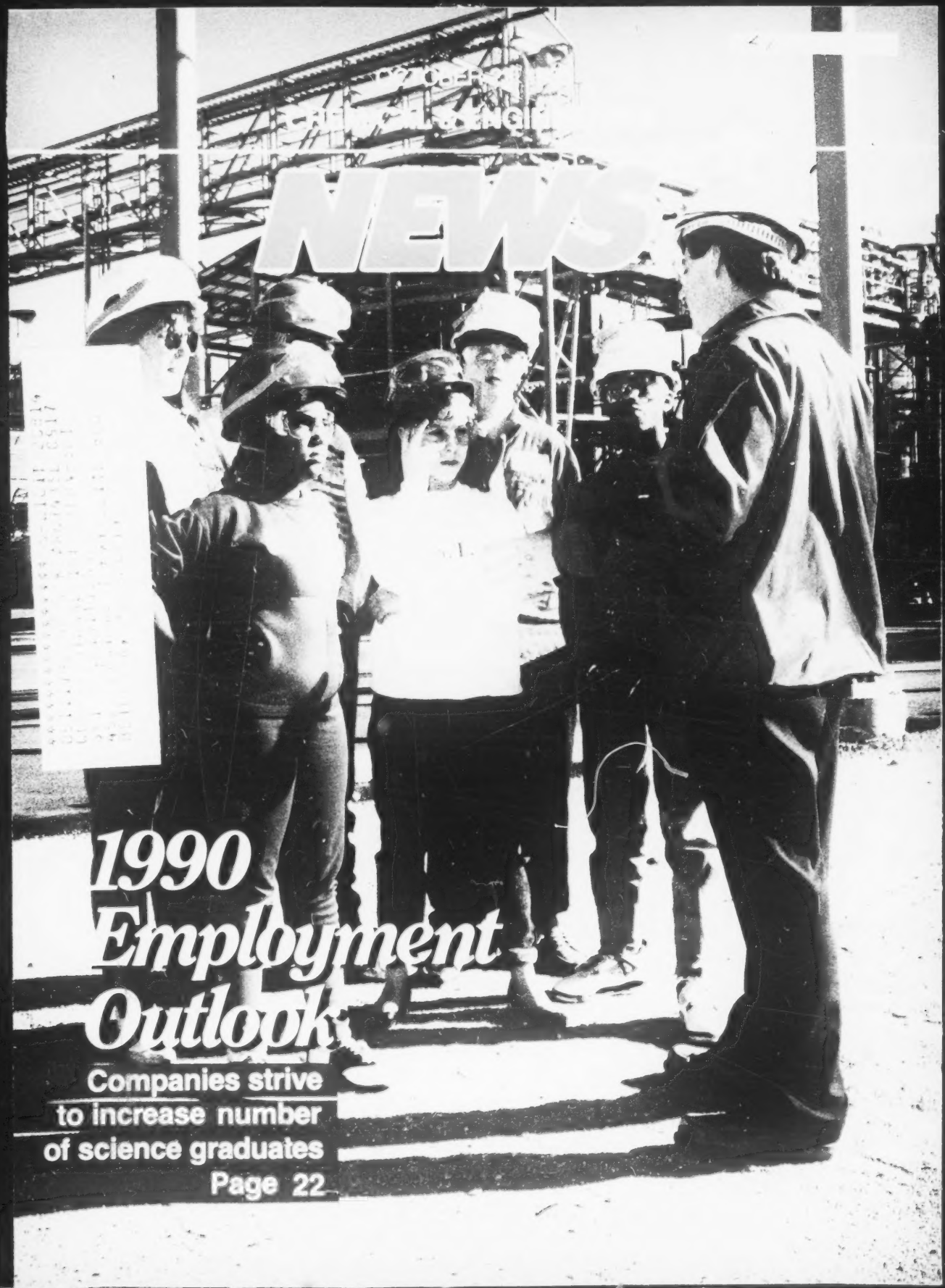
CHEMICAL ENGINEERING

NEWS



1990 Employment Outlook

Companies strive to increase number of science graduates

Page 22

CHEMICAL & ENGINEERING NEWS

Volume 67, Number 43
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OCTOBER 23, 1989

News of the Week

■ **San Francisco area earthquake left laboratories, plants shaken but in relatively good shape.** Page 4

■ **Deficit-demanded budget cuts probably will leave science relatively unhurt.** Page 5

■ **Aristech Chemical receives $25-per-share purchase offer from investment group headed by Jon M. Huntsman, chairman of Huntsman Chemical.** Page 5

■ **President Bush's decision to continue making chemical weapons despite planned global disarmament treaty draws fire.** Page 5

■ **National Medals of Science and Technology presented last week to 27 individuals during ceremonies in Washington, D.C.** Page 6

Cover: High school students tour Monsanto chemical plant in St. Louis

Letters 2

Concentrates
Business 7
Government 12
Science/Technology 17

The Departments
ACS News 41
Meetings 48
Newscripts 72

Business

Employment and salaries in chemical industry continue to increase, pushing up total industry compensation. **Page 10**

Degradable plastics may have significantly less impact on packaging market than was once thought. **Page 11**

Government

Environmental Protection Agency plans review of health and environmental safety effects of chlorofluorocarbon substitutes in effort to plan for safe, nontoxic alternatives. **Page 14**

Impact of leveraged buyouts as well as high costs of capital for research projects on the vitality of corporate R&D debated at recent conference. **Page 16**

Science/Technology

Complex Carbohydrate Structure Database developed at University of Georgia promises easier, more efficient searching for structures, information. **Page 18**

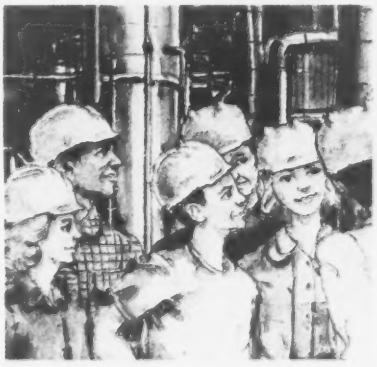
Center for Photoinduced Charge Transfer, one of 11 science and technology centers nationwide, opens at University of Rochester. **Page 19**

Books

"Pollution and the Struggle for the World Product" by H. Jeffrey Leonard leaves questions about potential links between environmental regulation and international economic competitiveness. **Page 39**

Awards

ACS winners: Nakanishi, Arnett, Bartlett, Grieco, Grubbs, Heathcock, Jorgensen, Schultz, Stille, Wasserman, and Wender. **Page 42**



Employment Outlook

C&EN's annual look at the job market focuses on efforts by industry to increase the number of science graduates and to improve precollege education. **Page 22**

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LETTERS

Hands-on chemistry exhibits

SIR: The article on precollege science and math education by Ward Worthy (C&EN, Sept. 11, page 7) provided a welcome status report. I would like to add a note to what was written about science museums and chemistry exhibits as a vehicle for science education. Science museums play a significant educational role in both formal and informal ways. But chemistry is difficult to do in the form of interactive exhibits. That is largely why chemistry has been sparsely represented in science museums.

The National Science Foundation has funded a collaboration between the New Curiosity Shop (NCS) and the California Museum of Science and Industry (CMSI) for development of hands-on chemistry exhibits. NCS has designed and developed 15 prototype hands-on chemistry exhibits that will form the interactive core of the "Molecules in Motion" exhibit mentioned in the article. The prototypes will be tested in the museum environment with several hundred visitors during October. CMSI will then incorporate the exhibit ideas into the designs for its chemistry gallery.

In addition, NCS will further refine some of these and other of its chemistry exhibits and produce copies for sale to science museums. These exhibits will provide the public of all ages with inviting, fun, understandable, concrete experiences with real chemical phenomena. The goal is to provide an avenue for reaching many people with the message that chemistry is intriguing, ubiquitous, important, and comprehensible at many levels.

Dan Chabay
President, New Curiosity Shop
Mountain View, Calif.

Auto emission control

SIR: In a letter to the editor (C&EN, Aug. 21, page 4), Rubin Weiner states that "bigger engines gulp more gas...and spew out more emissions." This is true for carbon dioxide to the extent that bigger engines use more fuel, but it is not true of the tailpipe emissions that are contributing to our current urban ozone and carbon monoxide nonattainment problems. Those emissions are controlled on a grams-per-mile basis, not on a grams-per-gallon basis. This is a common misunderstanding, because it seems so normal to believe that more gasoline going into the engine means more pollutants coming out.

In fact, a case can be made that more efficient cars worsen urban air pollution. Greater efficiency reduces the cost of driving, which, according to economists, increases the amount of driving done. Emissions increase as mileage driven increases even when gasoline consumption goes down, as it has done for most of the past decade.

Correcting this little misunderstanding will undoubtedly not change Weiner's views of the auto industry, but perhaps it will help clarify the relationship between fuel economy and tailpipe emissions.

There have been occasional calls for emission standards based on grams per gallon, so that reductions in gasoline consumption would be reflected in reductions in emissions. Neither the Environmental Protection Agency nor Congress has been very interested in changing the regulatory system, which is complicated and is working. The proposal for emissions averaging in the Administration's proposed Clean Air Act amendments would be a move in the direction of a surrogate grams-per-gallon standard, if one assumes that the more energy-efficient cars would be the ones with the lower-than-average emission levels and the less energy-efficient cars would be the ones with the higher-than-average emission levels.

David E. Gushee
Senior Specialist in
Environmental Policy
Washington, D.C.

Nuclear waste disposal

SIR: Edward J. Fritz has again assured us (C&EN, June 5, page 33) that high-level nuclear waste gives off too much heat to be buried. Why? Does waste spacing matter? Or rock type? Stress or lack thereof? Water content? Cooling time before burial? Simply saying there is "too much heat" is a very superficial judgment. Or is nuclear heat too much in any amount?

At the proposed Yucca Mountain repository, most of the waste canisters would be sized so as not to exceed a centerline temperature of 300 °C when the repository reaches its maximum temperature. The lower temperature in the surrounding welded volcanic tuff can be easily tolerated. Even at higher temperatures, the possibility of stress-induced fissures would be of little concern because of the waste depth and the dry climate.

Sweden is pursuing disposal in granite, with studies of migration of ele-

Growing Employment, Salaries Push Up Chemical Industry Compensation

Growing employment and increasing wages in the chemical industry continue to push up total personal earnings.

According to a Department of Commerce study, personal earnings for employees in the chemicals and allied products industry in the 50 states plus the District of Columbia rose last year to $44.34 billion, an increase of 9.5% from the year before. Personal earnings are total compensation, excluding fringe benefits, paid to employees.

The 9.5% increase for chemicals and allied products is well ahead of that for personal earnings for the U.S. as a whole—including all manufacturing and service industries—which rose 7.7% to $2.97 trillion. It also ranks ahead of the increase for total personal income, which rose 7.6% to $4.05 trillion. Personal income is earnings less payments for social security, medicare, and other social insurance programs, plus dividends, interest rent, and transfer payments. In 1987, chemical personal earnings rose 4.2%, compared with 7.0% for all personal income.

Of all U.S. industries, chemicals contributed about 1.5% of total earnings and about 1.1% of total personal income last year. This is about the historical norm for the industry.

Combining the Commerce Department figures with Labor Department data relating to total average annual employment shows that earnings per chemical employee nationwide last year totaled about $41,653, up 5.5% from the year before. In 1987, earnings per chemical employee increased only 3.7% from 1986; however, this figure has increased at an

New Jersey ranks first in personal income derived from chemical industry

Rank 1988	State	$ Millions	% change from 1987	% of total state personal income	% of total U.S. chemical income
	NEW ENGLAND	$ 1,978	7.1%	0.8%	4.5%
18	Connecticut	1,048	2.5	1.4	2.4
43	Maine	26	4.0	0.1	0.1
23	Massachusetts	741	14.0	0.6	1.7
40	New Hampshire	44	15.8	0.2	0.1
38	Rhode Island	100	5.3	0.6	0.2
46	Vermont	19	5.6	0.2	nm
	MID-ATLANTIC	12,903	11.0	1.6	29.1
9	Delaware	1,679	6.5	14.4	3.8
49	District of Columbia	17	6.3	0.1	nm
25	Maryland	480	8.6	0.5	1.1
1	New Jersey	5,411	11.5	3.2	12.2
5	New York	2,658	10.9	0.8	6.0
4	Pennsylvania	2,659	13.6	1.4	6.0
	GREAT LAKES	8,751	8.1	1.3	19.7
7	Illinois	2,474	8.3	1.2	5.6
12	Indiana	1,348	4.3	1.6	3.0
8	Michigan	1,897	10.5	1.2	4.3
6	Ohio	2,626	8.2	1.6	5.9
17	Wisconsin	406	8.3	0.5	0.9
	PLAINS	2,150	7.6	0.8	4.8
31	Iowa	206	6.7	0.5	0.5
29	Kansas	281	6.0	0.7	0.6
15	Minnesota	1,219	8.8	1.7	2.7
17	Missouri	1,119	8.3	1.4	2.5
32	Nebraska	205	8.5	0.9	0.5
42	North Dakota	41	2.5	0.5	0.1
40	South Dakota	44	4.8	0.5	0.1
	SOUTHEAST	10,275	6.7	1.2	23.2
26	Alabama	438	6.8	0.8	1.0
33	Arkansas	177	4.7	0.6	0.4
20	Florida	811	6.4	0.4	1.8
22	Georgia	643	6.5	0.7	1.5
24	Kentucky	518	7.2	1.1	1.2
14	Louisiana	1,284	8.7	2.4	2.9
30	Mississippi	216	3.8	0.7	0.5
10	North Carolina	1,505	7.1	1.6	3.4
13	South Carolina	1,307	13.7	2.9	2.9
11	Tennessee	1,395	3.0	2.1	3.1
16	Virginia	1,161	2.0	1.1	2.6
19	West Virginia	821	6.9	3.7	1.9
	SOUTHWEST	4,199	11.6	1.2	9.5
35	Arizona	134	24.1	0.3	0.3
49	New Mexico	17	0.0	0.1	nm
36	Oklahoma	109	7.9	0.3	0.2
2	Texas	3,939	11.4	1.6	8.9
	ROCKY MOUNTAIN	599	9.5	0.6	1.4
28	Colorado	317	3.3	0.6	0.7
34	Idaho	137	10.5	1.1	0.3
46	Montana	19	5.6	0.2	nm
37	Utah	106	27.7	0.5	0.2
45	Wyoming	20	25.0	0.3	nm
	FAR WEST	3,485	17.0	0.5	7.9
3	California	2,832	17.7	0.5	6.4
44	Nevada	25	0.0	0.1	0.1
39	Oregon	71	6.0	0.2	0.2
23	Washington	524	16.4	0.7	1.2
46	Alaska	19	0.0	0.2	nm
51	Hawaii	13	8.3	0.1	nm
	TOTAL	$44,340	9.5%	1.1%	100.0%

Note: Totals may not add due to rounding. nm = not meaningful.
Source: Department of Commerce

average annual rate of 5.6% since 1984.

Regionally, personal earnings totals from the chemical industry are highest in the Middle Atlantic states, according to the Commerce study, with total personal earnings of $12.9 billion in 1988, up 11% from the previous year. This is about 1.6% of total regional personal income and about 29% of total U.S. earnings from chemicals.

The Middle Atlantic region is followed by the Southeast, with a total of almost $10.3 billion in earnings derived from the chemical industry. This shows a year-to-year growth of about 6.7%. Earnings from chemicals in this region make up about 1.2% of total regional personal income and about 23% of U.S. chemical earnings.

From here earnings fall off rapidly by region. In the Great Lakes states, earnings in 1988 totaled $8.75 billion, up 8.1% from the year before and contributing about 1.3% of regional personal income and about 20% of total U.S. chemical earnings. Earnings in the Southwest totaled almost $4.20 billion, up 12%. This was 1.2% of state income and 9.5% of U.S. chemical earnings. These were followed by the Far West at $3.49 billion, up 17%; the Plains states at $2.15 billion, up 7.6%; and New England, $1.98 billion, up 7.1%.

The poorest region by far for chemical earnings comprised the five Rocky Mountain states, where those earnings were only $599 million. Although this was an increase of 9.5% over the previous year, it was just 0.6% of regional personal income and a scant 1.4% of total U.S. chemical earnings.

To find the number one state in total chemical earnings, don't look at Texas, with its great number of chemical plants centered around Houston. Texas is a distant second at $3.94 billion. The number one state is New Jersey with its concentration of drug industries and chemical headquarters and production. New Jersey's personal earnings from chemicals totaled $5.41 billion.

To fill out the Top 10, California is third at $2.83 billion, followed by Pennsylvania and New York in a tie at $2.66 billion, Ohio at $2.62 billion, Illinois $2.47 billion, Michigan $1.90 billion, and North Carolina $1.51 billion.

At the bottom of the list is Hawaii, whose $13 million was beat out not only by New Mexico at $17 million, but also by the District of Columbia (also at $17 million) with its public relations officers and others paid by the chemical industry.

It is in terms of year-to-year growth that some of the smaller states come into their own. The largest growth for the year was seen in Utah, where Huntsman Chemical has made its headquarters, at 28%. This is followed by Wyoming at 25%, perhaps heralding a healthy soda ash industry.

Following these are Arizona with a 24% rise, California 18%, Washington 16%, New Hampshire a little less than 16%, Massachusetts 14%, South Carolina and Pennsylvania, each a little less than 14%, and New Jersey almost 12%.

Not surprisingly, Delaware, with its small size and large concentration of chemical companies, leads in the chemical earnings as a percentage of total state personal income, at 14%. Interestingly, the second largest contributor to personal income there is state and local government, at $920 million, or 7.9%.

Delaware is followed at a far distant second by West Virginia at 3.7%, then New Jersey 3.2%, South Carolina 2.9%, Louisiana 2.4%, and Tennessee 2.1%. From there the percentages all cluster between as little as 0.1% and 1.7%.

This year, earnings of those employed in the chemical industry undoubtedly will rise again. However, the growth probably will not match the 9.5% yearly increase of 1988. Employment in the industry, although still increasing, is not moving forward as fast as it did last year. And wage increases are still holding at moderate levels.

William Storck

Limited impact seen for degradable packaging

The impact of degradable plastic films on certain packaging end-use markets may be significantly less than once thought. According to a recent study by Kline & Co., a New Jersey-based consulting firm, degradable films will account for only 11% of their 2.8 billion lb market potential by 1994. At current levels, this means that degradable films would make up about 5% of the total packaging film market.

To reduce solid waste and litter, degradable plastic films are expected to be targeted by consumers and legislators for six end-use areas: compost bags, grocery sacks, merchandise bags, trash bags, garbage bags, and diaper backing. However, the study reports, only compost bags, with 54% in degradable films, will account for a significant portion of the films' market potential. Figures for the remaining five markets show degradable films at levels of 17% in merchandise bags, and 11% or much less in the other areas.

Because of increased consumer interest, firms such as Mobil have started producing degradable plastic bags made from polyethylene. Degradable plastics, especially those that are biodegradable, can cost significantly more to produce, says Mobil. Biodegradable plastics based on cornstarch are being manufactured by companies such as Archer Daniels Midland and St. Lawrence Starch. Ampacet, among others, is using additives to promote photodegradability in plastic films.

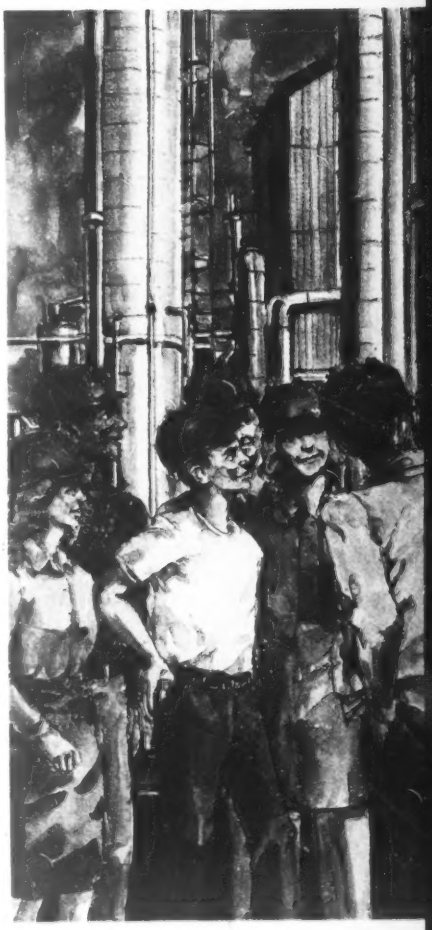
However, there are problems associated with the degradable materials. Often, they will only degrade with relatively long exposure to the environment. Research at the University of Arizona has shown that burying most degradable substances in landfills will inhibit their breakdown for decades.

The Kline & Co. report suggests that the waning support of decisionmakers will influence the decreased impact of degradable plastics in packaging film markets. The Environmental Protection Agency, in a 1988 report on solid waste, along with plastics industry trade associations and certain environmental groups, shows more support for managing solid waste through a four-step process involving reduced use, recycling, incineration, and landfilling.

Ann Thayer

1990 Employment Outlook

Bette Hileman, C&EN Washington



◆ *Career Opportunities for Chemical Professionals*

The employment market for chemical professionals was more robust this year than at any time in the recent past. Recruiters report that there seemed to be more jobs, particularly for B.S. and M.S. chemical engineers and Ph.D. chemists, than there are candidates to fill them. As a result, both chemists and chemical engineers are getting higher salaries. Furthermore, some companies even began to offer bonuses to new graduates who accept job offers. Also, companies believe they may need to hire more foreign graduates who do not have permanent residency status in the U.S. And more job candidates this year have been bidding one firm against another for salaries.

◆ *Industry Strives To Increase Science Graduates*

In response to an impending shortage of scientists and engineers, industry is using a variety of techniques to increase the supply of graduates and to improve precollege education so students will be prepared and motivated to enter these fields. Page 23

◆ *Demand*

Demand for chemical professionals, strong in 1988, is even stronger this year. For B.S. and M.S. chemical engineers, especially, there appears to be a tightening supply-demand crunch. According to the College Placement Council's survey, the number of offers for chemical professionals rose markedly. And the latest ACS employment clearinghouse had more jobs listed than candidates seeking positions. Page 29

◆ *Salaries*

Starting salaries for newly graduated chemical professionals are up at all degree levels this year. For chemical engineers, they rose 6% at the B.S. and Ph.D. levels and 9% at the M.S. level. Salaries of experienced chemists rose just enough to keep up with inflation. Page 33

◆ *Career Planning*

The American Chemical Society and other organizations can provide a variety of useful information to people seeking advice about careers in chemistry and chemical engineering. This section lists services, sources of information, and organizations that can supply guidance about careers. Page 35

Industry Strives To Increase Science Graduates

Industry is using an array of techniques to encourage more students to major in science and engineering

A crisis is developing in the supply of scientists and engineers entering the work force. That is the consensus of the National Science Foundation, some academic personnel, and many leaders in the chemicals and allied products industry.

NSF predicts that by the year 2006 the U.S. will have a cumulative shortfall of 675,000 people with bachelor's degrees in natural science and engineering. Similarly, NSF projects that by 2006, 24,000 new jobs in these fields requiring Ph.D.s will be created annually, but only 10,000 Ph.D.s will be granted. Even if salaries respond enough to increased demand to attract more Ph.D. candidates, there likely will be an annual shortfall of 7800 Ph.D.s. Already, the shortage is becoming evident. This year for the first time since the late 1970s, recruiters report that there seem to be more jobs for new B.S. chemical engineers and Ph.D. chemists than there are qualified candidates to fill them.

In response to this impending crisis, the chemical industry and others have taken a number of steps to attract more students into science and engineering and to improve precollege science and math education so students will be prepared and motivated to enter these fields. Efforts are being made at nearly all educational levels—precollege, undergraduate, and graduate but the major focus of industry's efforts has been directed at high schools and middle schools.

At the annual meeting of the Council for Chemical Research early this month in Parsippany, N.J., Mary L. Good, senior vice president for technology at Allied-Signal, said, "About the year 2000, the shortage of Ph.D.s [in science and engineering] will become critical. If we expect to have the human resources we need to sustain our research endeavor, we are going to have to find better ways to interest more of our people in math and science."

Why is a large shortfall in scientists and engineers predicted for the near future? Only a few years ago, there was such an excess of chemical engineering graduates that many couldn't find work and large numbers of chemists were being laid off in early-retirement programs.

Several factors will probably contribute to the shortage. First, industry, academia, and government are expected to employ a steadily increasing number of scientists and engineers over the next 20 years. The chemical industry, as well as much of the rest of the economy, is increasingly dependent on highly trained scientists and engineers to maintain profitability and develop new products. "The high-technology economy requires an extraordinary investment in basic scientific research. It is knowledge- rather than energy-, resource-, or personpower-intensive," says Edward J. Bloustein, president of Rutgers University.

At the same time that the number of job openings is expected to rise, the college-age population in the U.S., which has been declining since 1980, will continue to decrease through 1996. Census Bureau fig-

ures indicate the population of 18- to 24-year-olds will reach a low of 24 million in the mid-1990s, compared with 30 million in 1980. In addition, a smaller and smaller part of this diminishing number of students is choosing to pursue science majors. In 1973, 11% of college freshmen intended to major in biological or physical sciences or mathematics. By 1988, that percentage had dropped to 6%. The number of bachelor's degrees in chemistry awarded last year was the lowest in two decades.

Another factor that is expected to contribute to a decreasing pool of scientists is that by the end of the century, only 15% of net new entrants to the labor force will be white males. Currently, the vast majority of scientists and engineers are white males.

Unless the proportion of white men that major in science or engineering rises dramatically, women, blacks, Hispanics, and new immigrants will have to make up the shortfall. Yet most members of these groups have traditionally shunned science and engineering careers. For example, in 1987 blacks earned a total of 12 of the 3716 engineering doctorates awarded and only 16 of the 3210 Ph.D.s in physical sciences. The number of B.S. degrees in science and engineering granted to blacks and Hispanics was actually lower in 1985 than in 1979. Moreover, women, though their share now is greater than in the past, were awarded last year only 16% of the doctorates in physical sciences and 7% in engineering.

Already now for more than a decade, chemistry and chemical engineering departments in colleges and universities have not been able to recruit enough U.S. citizens as graduate students. They have filled their excess openings with foreign students. In 1987, for example, foreign students earned 40% of the Ph.D.s in chemical engineering.

A final contributing factor that dims the prospects for recruiting enough students into science and engineering is that the achievement of U.S. elementary and high school students in science is very low when compared with that of other developed countries.

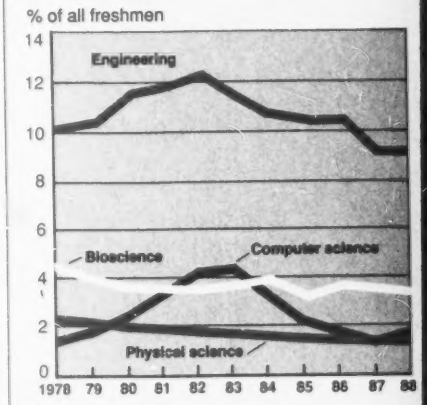
In 1988, the International Association for the Evaluation of Educational Achievement compared the science achievement of students in 15 developed countries. It found that at the fifth-grade level, U.S. students stood about in the middle, similar to students in Italy and Australia, while Japan and Korea led. But by the ninth grade, American students ranked next to the last; only Hong Kong was lower on the scale. Ninth graders in Hungary headed the list, followed by Japan and the Netherlands.

Even when only those students taking advanced high school courses in science were compared, U.S. students ranked in the middle in physics, third from the last in chemistry, and at the bottom in biology. Apparently, something happens to turn off the U.S. students to science between the fifth and ninth grades, and to dampen the achievement of even the best students in high school.

To better prepare students so they have the background and motivation to study science and engineering, and to encourage able college-age students to major in these fields, industry, either independently or in partnership with government or academia, has initiated or joined a great many programs to improve college and precollege education.

Good: shortage will be critical

Fewer freshmen have planned sciences or engineering major



Source: American Council on Education

Some of the programs are aimed directly at increasing the supply of scientists and engineers. Others, such as research grants, have multiple purposes, only one of which may concern supply or educational quality.

Industry provides a great deal of financial aid to undergraduate and graduate education. Nearly 90% of these funds supports specific research projects or specific research areas in which the company has an interest. The aid that industry gives for such research has a direct effect on the supply of graduate students because much of it is used for fellowships, thus creating new openings for graduate students. The amount of corporate support for chemistry and chemical engineering departments has increased markedly since 1981. For example, surveys carried out by the Council for Chemical Research show that industrial support per faculty member in the chemical engineering departments responding to the survey increased from $10,540 in 1981 to $33,860 in 1987. For chemistry department respondents, the percentage increase was even greater: The support grew from $3300 per faculty member in 1981 to $13,340 in 1987.

The approximately 12% of corporate funds that are uncommitted also may serve to increase the number of graduate students. Some of these funds are used by department heads

to identify promising undergraduates and pay for their visits to graduate schools, where they are informed about the programs, for example.

Corporate aid to chemistry and chemical engineering departments also serves to attract more graduate students by improving the general quality and prestige of these departments. It makes it possible for them to do some kinds of important research that would otherwise be too expensive.

The effect of industry's support on undergraduate education is less clear. Some of the discretionary funds that companies provide are used to recruit undergraduates and thus help increase the number of science and engineering majors. According to John T. Lund, executive director of the committee on educational aid at Du Pont, department heads often use part of these discretionary funds to send representatives to high schools to try to explain the value of chemistry and chemical engineering.

But the research money industry provides chemistry and chemical engineering departments has both a positive and negative effect on undergraduate recruiting and retention. At the same time that it increases the prestige of the department and thereby attracts more undergraduates by providing stimulating, and sometimes personally lucrative, research opportunities for faculty members, it may divert them away from another important function—providing high-quality teaching for undergraduates. Most observers recognize that research is an important component of higher education. Some believe, however, that the increased focus on research has caused faculty members to lose contact with undergraduates.

Many in academia are concerned that undergraduate chemistry classes are taught too often by the least qualified instructors in large classes and uninspiring labs. Consequently, large numbers of students who might otherwise be interested in chemistry are turned off, they say. These critics claim that some chemistry faculty members concentrate too much on research.

"Faculty members are urged to become entrepreneurs, to start companies, to obtain patents, to acquire venture capital, and to establish international reputations," says Glenn A. Crosby, professor of chemistry and chemical physics at Washington State University. "The system is badly out of balance," he adds. "Teaching is often left to those who can't make it in research."

Porter: academic Ph.D. recruitment

The Council for Chemical Research has established a committee that solicits unrestricted funds from member industries and gives these funds to chemistry and chemical engineering departments to use in any way they see fit. Recipients consider these funds very useful because they are untargeted and can be used in critical areas for maximum impact. By strengthening the departments or being used for recruiting, this money may help attract more students into chemistry and chemical engineering. However, the unrestricted funds collected by the Council for Chemical Research have declined from a high of $675,000 in 1985 to about $450,000 in 1989, when they were just slightly higher than in 1988.

Some companies that hire chemical professionals also support cooperative students. These students work full-time at a particular company for two or three semesters during the regular four undergraduate years and take courses during the summer to make up the material they missed during the nine-month school year. Cooperative programs expose students to the practical applications of their courses in industry and thereby may help motivate some who would otherwise change their majors from science or engineering into some other field. In 1988, Congress' Office of Technology Assessment recommended cooperative programs as one way to motivate students and keep them from dropping out of science and engineering majors.

These programs have been going on for decades. However, a number of companies that never before had such programs are now starting them, says Daniel T. Hanson, job coordinator for the chemical engineering department at Texas A&M University.

In addition, in the past few years, some firms that hire chemical professionals have increased the number of scholarships and fellowships they provide. For example, Phillips Petroleum has raised its undergraduate scholarship support at least 30% in the disciplines that are in short supply for the company, says William K. Dausses, director of employment and placement. Phillips also

Roger Timmer (left), an employee of Lacks Industries, an automobile parts supplier in Grand Rapids, Mich., explains plant operation to teacher-intern Peter Haverkamp

has increased the number of fellowships it grants at the graduate level. Several other companies have taken similar steps to augment scholarships and fellowships in areas in which shortages of scientists and engineers are now developing.

During the past 15 years, industry has joined in several partnership programs that are aimed at increasing the numbers of undergraduate and graduate majors in science and engineering. Most of these programs are directed at minorities. One of the oldest efforts is the National Consortium for Graduate Degrees for Minorities in Engineering (known as the GEM program). Begun in 1976, it is a partnership of 55 science and engineering schools and 65 corporations and independent research labs. So far, it has provided scholarship support to more than 900 minority students in engineering at the master's degree level. Recently, GEM announced two new efforts. One is a fellowship program for minority students who wish to pursue doctoral degrees in the sciences, and the other is a similar program for doctoral degrees in engineering.

Dennis J. Kreil, Ph.D. recruiting manager for Dow Chemical and vice president of science programs for GEM, says: "There is a real need for fellowship support for minority students in graduate education. When you look at the population of students graduating each year with Ph.D.s, you can see that minorities such as blacks, Hispanics, and American Indians are vastly underrepresented."

GEM Ph.D. fellowships cover all tuition and fees, fund annual stipends for five years, and provide salaries from summer research internships with sponsoring employers. Applicants must be U.S. citizens who are black, Puerto Rican, Mexican-American, or American Indian. In 1990, 25 fellowships for each of the Ph.D. science and engineering programs will be provided, and 40 will be given for each of these programs annually thereafter. In addition, about 150 M.S. engineering fellowships are given each year. Mentors are provided for the fellowship recipients at both the university and sponsoring company.

Another partnership that may help attract undergraduate and graduate students to science and engineering is the Presidential Young Investigators (PYI) program. Jointly sponsored by NSF and corporations, it provides research support to about 200 young faculty members in engineering, math, and all of the physical and life sciences, as well as behavioral and social sciences. According to Terence L. Porter, director of the research career development division at NSF, the primary goal of the program is "the recruitment and retention of high-quality young Ph.D.s in academic careers." It grew out of a concern that the best and brightest Ph.D.s were leaving academia for higher paying jobs in industry, thereby depriving the next generation of scientists and engineers of first-rate professors.

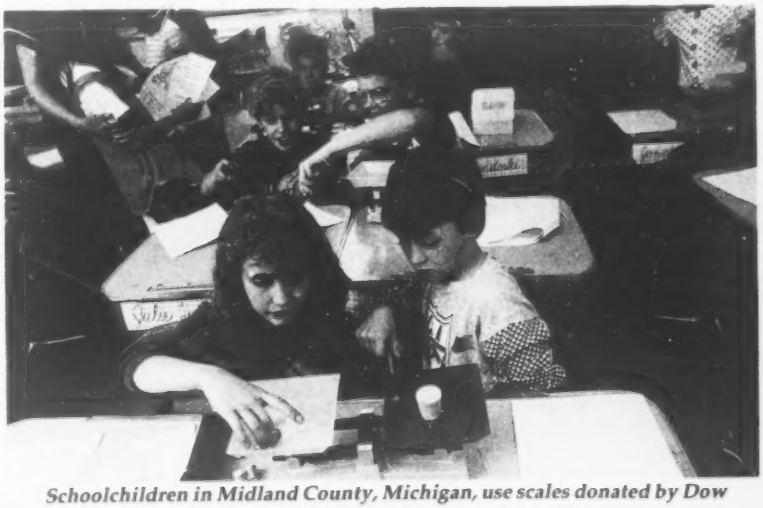
Young faculty who are chosen to participate in the program receive an annual grant of $25,000 from NSF and up to $37,000 more in annual funds if they are matched by contributions from corporations or nonprofit institutions.

Although the major goal of this program concerns faculty, one probable secondary effect is that it enables academic departments to recruit more students. A strengthened department with brilliant, in some cases well-known, instructors is likely to attract more graduate students and sometimes more undergraduates.

One aspect of the program that has shifted somewhat from what was planned originally is the lower emphasis on teaching. "From the beginning, this program was envisioned as having an important teaching emphasis. After all, we were putting in place the key teachers of the next generation of advanced scientists and engineers," says Porter. However, the program today seems to have little to do with teaching. NSF says only that a PYI award should not change the normal teaching requirement of the affected faculty member and that potential as a teacher is one qualification for nomination.

The PYI program may act as a double-edged sword in its effect on recruiting more undergraduates into science and engineering. The greater prestige a department gains from having young faculty members in the program may help in recruiting. But the time participating faculty members must spend soliciting matching funds and the great emphasis the program puts on their research may detract from the participants' effectiveness as teachers.

Industry supports, at least in part, a large variety of programs at the precollege level that are aimed at encouraging and preparing young people to major in science and engineering. Many of these are partnerships between industry, universities, and, in some cases, government. L. Sandy MacLean, vice chancellor for student affairs at the



Schoolchildren in Midland County, Michigan, use scales donated by Dow

University of Missouri, St. Louis, estimates that there are at least 200 such programs. In addition, individual companies, or sometimes industrial organizations, also carry on independent precollege programs to accomplish the same purposes.

Over the past two years, NSF has funded, or is about to fund, in cooperation with industry about 46 partnership projects that aim to improve precollege science and math education and increase the supply of scientists and engineers. Industry's "huge pool of skill and knowledge in technical areas constitutes a resource which can be, if used appropriately, a tremendous asset in improving science and mathematics education," says Charles R. Eilber of the education directorate at NSF.

One of the cooperative projects NSF is involved in is the Bridge program. In addition to NSF, it is funded by the state of Missouri, Union Electric, Monsanto, and Ford Motor. Students from five high schools in the St. Louis area participate in the program. The project has several components: college visits for the high school students; an academy at the University of Missouri that 50 high school students attend each Saturday for enrichment courses in science and math; a summer science academy at the University of Missouri involving 97 students; a combined credit program in which high school students earn high school and college credits simultaneously; a summer link program in which 50 high school seniors or recent graduates take summer courses at the university and are provided with jobs in the afternoon; and tutoring programs in all five high schools.

Students tour Monsanto's John F. Queeny plant in St. Louis

Another partnership called the RET-E^3 program works with elementary and secondary teachers rather than students. It is directed by the Coalition for Excellence in Science and Math, based at Grand Valley State University in Allendale, Mich., and sponsored by NSF, the coalition, Grand Valley State University, cooperating school districts, and businesses and industries. The program has several phases. First, outstanding science and math teachers are honored and most of them participate in a summer work internship in industry, where they learn some of the skills and technologies that are needed to be successful in a business organization.

As a part of the internship, the teachers investigate career opportunities for students and the skills and knowledge students need to foster during their secondary and college education. Afterward, the participants develop in-service training workshops to share what they have learned with other teachers.

Lester Wallinga, science teacher at Calvin Christian Junior High in Grandville, Mich., expresses the satisfaction that many of the teachers feel about their internships: "I experienced the revolution that is going on in industry. I saw the automated machines, the computer-assisted 'everything,' and the very evident pride of some of the older workers as they showed me their new high-tech skills."

According to David C. Tanis, executive director of the coalition, the RET-E^3 program provides teachers an opportunity to be inside an industry, revitalizes them, and enables them to develop new curricula. The program also benefits companies. "It helps industrial personnel understand problems in education in a new light," he says.

Last year, six Ohio companies, precollege teachers, and university teachers formed a partnership coordinated by Miami University chemists John P. Williams and Arlyne M. Sarquis. In the 1988–89 school year, 72 teachers from grades four through 12 and science coordinators participated in three industrial workshops. With lectures, laboratory, and discussion, the teachers were taught general principles of industrial chemistry, as well as the specific chemistry used by the six participating companies. They were instructed in activities and experiments they could use in their classrooms by industrial chemists and by university faculty. Then the teachers spent one day on site at one local company. After each session, the teachers tried out in their classrooms one or more of the activities they had been taught.

Good communication was established between the participating teachers and the mentors from industry and the university, which helps the teachers in their classrooms, Williams says. "A much larger number of teachers will be affected by the program as workshop graduates conduct training workshops within their own school districts," he notes.

The Partners in Science program is another effort aided in part by industry whose main purpose is to encourage talented young people to major in science. Coordinated by the Liberty Science Center and Hall of Technology, a new museum of contemporary science and technology in Jersey City, N.J., the program consists of research internships for high school students. This past summer 34 high school seniors spent seven weeks doing research. Seven students were assigned mentors in industry and 26 had mentors at universities. The students also attended biweekly seminars at the Liberty Science Center. The students found that personal contact with their mentor was the most important aspect of the program, says Dana Levine, outreach coordinator for the Liberty Science Center.

So far the program seems very successful. All of the 18 students who participated in the summer of 1988, the first year of the project,

are now enrolled in college and 17 intend to major in science or engineering. This project is funded by the Geraldine R. Dodge Foundation.

Companies also have been cooperating to produce instructional materials to be used in science classes across the country. One such effort, the Science Screen Report, is a series of videotapes and accompanying teachers' guides for classroom use in junior and senior high school. Seven videos are made each year concerning topics in chemistry, physics, biology, medicine, the environment, engineering, and other technological subjects. The series is underwritten by about 300 corporate sponsors, many of which are chemical companies, who donate the programs to schools in the communities where they operate. Currently, the series is used in about 5000 schools in nearly 2000 communities.

Chemical Education for Public Understanding Program (CEPUP) is another partnership effort to develop innovative science curricula. It is operated as part of the Lawrence Hall of Science at the University of California, Berkeley, and supported by NSF and a large number of major donors, including Arco Foundation, Chemical Waste Management Inc., Chevron Chemical, Dow Chemical, Hewlett-Packard, IBM, Shell Oil Foundation, and Union Carbide. The curriculum materials developed by CEPUP are specifically targeted toward helping students and the general public gain an understanding of chemicals and how they fit into society. Each curriculum module uses six to 10 hands-on activities to integrate the study of chemical concepts with societal issues. The modules are made for use both in middle school and in community education.

Many chemical companies have independently become involved in a wide variety of programs to improve science education. One such company is Monsanto. In addition to its support of the Bridge program, Monsanto participates in a large number of educational projects, most of them in the St. Louis area. For example, a Monsanto grant enabled the Mathematics and Science Education Center to begin developing biotechnology curriculum materials for children and adults and to start instructing teachers in the use of the materials.

Monsanto also participates in Inroads, a nonprofit organization that aims to interest precollege and college minority youth in engineering, science, and business. As a part of the program, Monsanto sponsored 22 minority student interns in the summer of 1988. The company supports a similar program called Horizons, which offers summer employment for minority high school students who are interested in careers in math and science.

In addition, Monsanto gives college scholarships in a novel way. The company contributes surplus equipment to colleges, which then offer scholarships equal to the value of the donated equipment.

Monsanto contributes significantly to the science fair for school-age children in St. Louis by providing financial, scholarship, and volunteer support. John L. Mason, president of the Monsanto Fund, which manages and finances most of Monsanto's educational programs, says, "We can imagine no investment with a greater return—for Monsanto or for the country—than education and, particularly, science education."

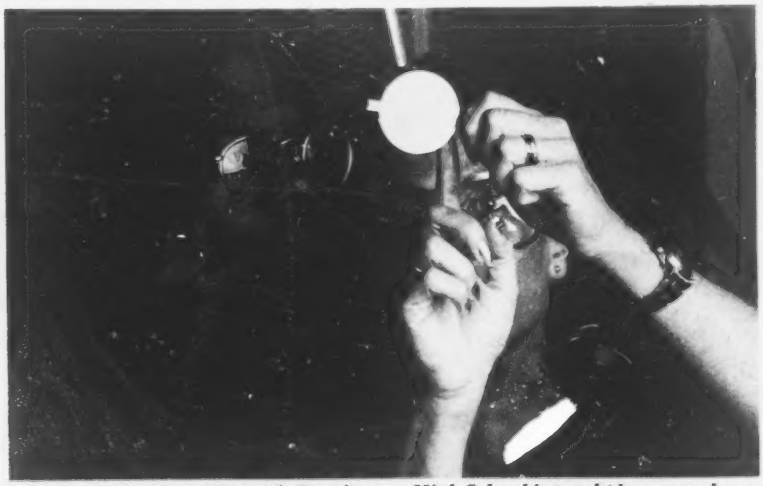
Dow Chemical is another firm that is involved in a large number of programs to improve science education on the precollege level.

Each summer, Dow sponsors 15 honors students from Detroit's Renaissance High School for eight weeks of research and engineering activities at the company's Michigan division. Students are assigned college-level projects that relate to their interests under the direction of Dow scientists, who serve as mentors and counselors. The students also are offered college scholarships. So far, most of the participants in the program have enrolled in college with majors in science, math, or engineering.

Another of Dow's projects is an entertaining, informative chemistry lab at Lansing's Impression 5 Science Museum. Dow built the lab and supplied it with the materials and staff to operate it. Opened in 1986, it provides a variety of demonstrations and workshops for school classes and the general public.

Dow also has contributed equipment for use in science classes to every public school in Midland County and instructs elementary and intermediate teachers on the effective use of the equipment.

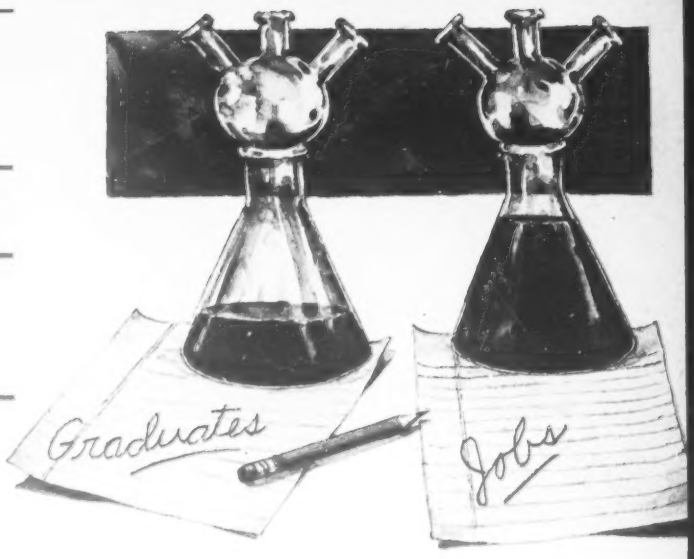
The programs industry has initiated to improve precollege science education are so new it is impossible to judge their impact. However, the great number and variety of these programs indicate that industry is aware of serious problems in science education and that many companies are willing to invest both time and money to try to change the situation. □



Honors student from Detroit's Renaissance High School is taught by researcher during eight-week internship at Dow Chemical's Michigan division

Demand

The employment market for chemical professionals was stronger this year than at any time in the past decade



Demand for chemical professionals, strong in 1988, is even stronger this year. For chemical engineers, especially at the B.S. and M.S. levels, in fact, there appears to be a supply-demand crunch, which shows no signs of abating. Recruiters for the chemical industry report that the situation is not a crisis now, but could become one in a year or two.

Some chemistry department spokesmen also characterize the industrial job market as "excellent." In general, they say, demand is higher in 1989 than it was last year.

Chemical engineering department spokesmen report an even rosier picture from the graduates' perspective. Jobs outnumber candidates by a wide margin, they say. "A seller's market" and "excellent to overwhelming" are phrases they use.

The College Placement Council's July college recruiting survey also reflects high demand for chemical professionals. Except for M.S. graduates in chemistry, the numbers of offers for both chemists and chemical engineers at all degree levels rose markedly from July 1988. B.S graduates in chemistry received almost twice as many offers as of last June 6 than they received by the same date in 1988. Chemical engineers with a B.S. degree received 54% more offers. Similarly, Ph.D. chemistry graduates had 14% more offers, and those with a Ph.D. in chemical engineering about 50% more.

Figures from the latest ACS employment clearinghouse at the ACS national meeting in Miami Beach indicate high demand for chemical professionals as well. According to Joan E. Wheeland, coordinator for ACS employment and career services, which operates the ACS National Employment Clearing House, there were 601 positions posted but only 469 candidates there. In all, about 2600 interviews were arranged. From the job seekers' point of view, this was the best clearinghouse ACS has had in at least 16 years. It was also unusual, Wheeland says, because a very large number of postdoctoral positions were listed. Because postdoctoral positions are often a second choice for graduating Ph.D. chemists who can't find a job in industry or academia, a substantial rise in open postdoctoral positions usually indicates that more of these candidates found satisfactory work elsewhere.

An unusual combination of circumstances has led to this situation in which an ample supply of jobs exists for both chemists and chemical engineers. First, by most measures, the economics of the chemical industry were extremely favorable in 1988 and in the first half of 1989. In 1988, U.S. output of all types of chemicals was 8% higher than the year before, and earnings of major chemical companies rose 67% compared with a 52% increase in 1987. Capital spending in the chemicals and allied products industry was up 17% and outlays for research and development rose an estimated 12%.

Output so far this year, moreover, is running 7% above that of a year earlier. R&D spending is rising further. However, earnings growth slackened off in the first half of

Bachelor's degrees in chemistry have declined in past decade, while Ph.D. degrees climbed

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987[a]	9,661	1738	1976	4983	1184	497

a Preliminary figures. **Source:** National Center for Education Statistics

1989. For major chemical companies, earnings in the second quarter were only 3% higher than in the same period last year. But, profit margins are still predicted to be about the same as in 1988, and industry spokesmen are optimistic about the outlook for the year as a whole.

Coincident with the healthy economy was an estimated further decline in the supply of newly graduating chemists and chemical engineers at both the B.S. and M.S. levels in 1989. Although the number of chemists and chemical engineers graduating at the Ph.D. level probably increased slightly, the number of Ph.D. chemists who are U.S. citizens fell. Therefore, the supply of new entrants into the chemical profession of all types and at most degree levels declined in 1989, and it is predicted to continue falling for a few more years.

High demand has had several effects, some routine and expected, but others that are almost unheard of in the hiring of chemical professionals. As usually happens in such a situation, starting salaries for both chemists and chemical engineers are up. However, the way in which they rose is rather unusual this year. Salaries offered to newly graduated candidates in the spring of 1989 were nearly $2000 to $3000 higher than offers in the fall of 1988. Usually, when a salary schedule is set in the fall, it remains fairly constant throughout the school year. This year, as the economy remained strong over the course of the school year and companies had more and more difficulty finding enough candidates, salaries escalated.

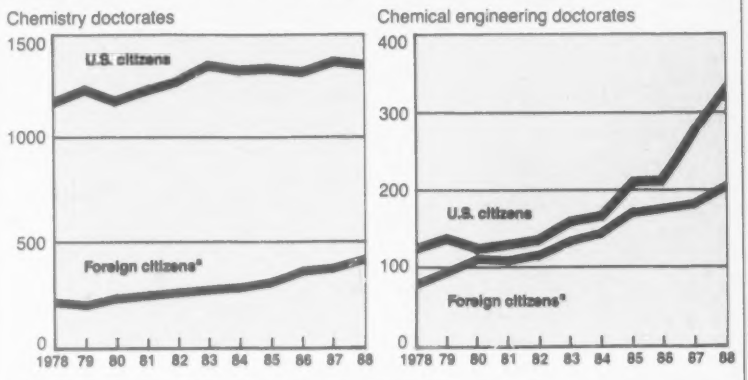
A second, more unexpected effect was that a number of companies began giving bonuses, ranging from $1000 to $10,000, to new graduates who accepted job offers. Some bonuses were awarded to Ph.D. graduates in chemistry; many more were given to chemical engineering graduates at all degree levels, but especially to those with a B.S. Such bonuses have several different names: sign-on bonus, report-to-work allocation, relocation fee, early decision bonus, special house-hunting bonus. All are a form of one-time compensation offered only to new hires. Some depend on the number of weeks the candidate takes to accept an offer. At least one Texas-based oil company gave $3000 if its offer was accepted in one week, $2000 at two weeks, and only $1000 if the candidate took three weeks to decide. Nearly all spokesmen from academia and industry contacted by C&EN had heard about such bonuses. Pharmaceutical and oil companies are mentioned most often as having engaged in this practice, but some chemical producers are also said to have awarded such one-time compensation to at least some of their new hires.

"Some companies are having difficulty hiring people. So to gain a competitive edge, they become involved with some one-time cost approaches," explains Fred O. Schulz Jr., manager of hiring for B.S.- and M.S.-level candidates in research and product development at Procter & Gamble. According to Rebecca J. Simon, placement director at the school of chemical sciences at the University of Illinois, "Companies are worried about such signing bonuses," because it partially undercuts their ability to recruit new employees. She points out that it is important to distinguish between bonuses and traditional recruiting strategies such as scholarships and summer hires.

Another related effect of high demand is that candidates have been bidding one company against another for salaries. Bidding has always happened to some degree, but seems to be much more widespread this past year. One company offers a salary to a graduating student and a second company makes a higher offer. The student then asks the first company if it can match or beat the second offer. The practice, according to one spokesman from academia, "is creating real problems for relations with current employees" because the new employee may be hired at a higher salary than those who have been employed for one or two years. Many industrial recruiters, however, say they never hire new employees at salaries that match or exceed those of existing employees because it would create severe personnel problems.

A final result of high demand is that companies are now considering whether in the next year or two they may need to employ more foreign graduates who do not have permanent residency status in the U.S. If a firm can prove to the Immigration & Naturalization Service that it has need for a candidate with particular skills and cannot find one who is a U.S. citizen or has a permanent visa, the company can legally hire a foreign graduate with only a temporary visa. Until now, most companies have not made the considerable effort required to go through this procedure. "So far we have tried to avoid that issue. It's so time-consuming and expensive. But if we can't find these skills in the domestic work force, sponsorship is a logical option," says William F.

Ph.D.s in chemistry and chemical engineering earned by foreign students have doubled in past decade



[a] Students on temporary visa. **Source:** Doctorate Records File, National Research Council

Dausses, director of employment and placement for Phillips Petroleum. "The lack of domestic candidates for special needs will probably make sponsorship a part of normal business," he adds.

Chemistry department spokesmen at some major universities offer glowing reports of the job market for their graduates. Carole B. Moody, assistant director of student services in chemistry at the University of Michigan, Ann Arbor, says she had "three times more offers this year than last for B.S. candidates," even while the number of graduates stayed the same. She doesn't know of any Michigan chemistry candidates at any degree level who couldn't find a job. The number of recruiters on campus was "up slightly," with oil companies playing a somewhat larger role in the hiring picture.

Audrey L. Aylesworth, placement coordinator in the chemistry department at the University of Wisconsin, Madison, believes the job market for B.S. chemists is not quite that outstanding. She characterizes it only as "pretty good." However, chemistry Ph.D.s at Wisconsin were extended many more offers than the year before. In the 1988–89 school year, there were 26 unaccepted offers, whereas in 1987–88, there were only 10. Ph.D. candidates who took industrial positions averaged three offers each compared with 2.6 last year.

Four of the Ph.D. graduates at Wisconsin went directly to college or university teaching positions without first doing a year or two of postdoctoral work. To obtain an assistant professorship immediately after earning a Ph.D. was "unheard of five years ago," Aylesworth says. From this she concludes that demand for chemistry faculty must be high right now.

The University of Illinois' Simon found the industrial job market for chemists at all levels about the same as it was last year. For B.S. chemical engineering graduates, however, 1988–89 was far better. They received 148 offers, compared with 113 the year before. "Companies were complaining about not finding enough B.S. chemical engineering candidates. They'll be complaining more next year," she predicts.

Firms are now beginning to realize that "hiring a fairly consistent number of new graduates each year is a wiser business strategy," because it helps avoid the boom-bust cycle that discourages students from majoring in chemical engineering, Simon observes. She also notes that "oil companies are back much more in force than they had been" and quite a few new companies are recruiting. "Mergers are no longer having a negative effect on hiring," she says.

"In academia, it's thick and heavy," she adds. "The nation's faculty is aging. I think we have a serious problem in finding enough faculty," she comments.

R. Bryan Miller, chairman of the chemistry department at the University of California, Davis, found the job market excellent for B.S. candidates. "We had contacts from quite a few places that are looking really hard for B.S. people," he says. For M.S. and Ph.D. graduates, demand "seemed better this year than last, and last year was good." Almost everyone graduating from his department has found a position, he notes.

He, too, believes competition in the academic market is very keen. "I think that's only going to increase as time goes on in light of the predicted replacement of a very large percentage of current faculty in the next 10 to 15 years," he says. "One of the real problems I foresee is meeting the demand for Ph.D. chemists from both academia and industry."

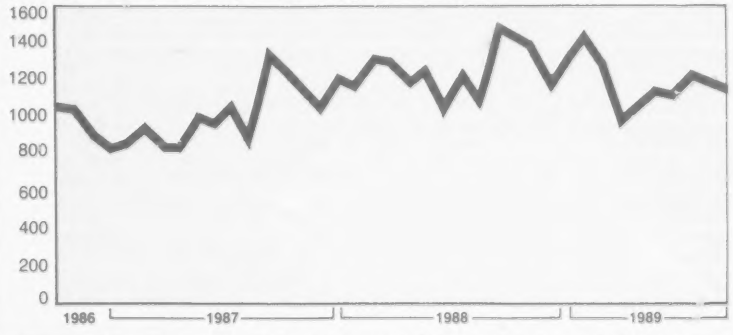
Steward J. Strickler, associate chairman of the chemistry department at the University of Colorado, also notes that, as far as he knows, all the chemistry graduates in his department found jobs. "There were several recruiters who came to the department seeking candidates for available jobs but couldn't find anyone to interview," he says.

Chemical engineering departments report even stiffer competition among companies for their graduates. William L. Conger, head of the chemical engineering department at Virginia Polytechnic Institute & State University, Blacksburg, says B.S. graduates there received four or more offers each, with some of them offered positions before Thanksgiving, which is unusual. He also notes that starting salaries kept escalating over the year. All the M.S. and Ph.D. candidates who wanted a job succeeded in finding one, he says.

One reason Conger gives for increased demand is that oil companies have started to hire again. "They are a significant influence on the market," he says. He claims that some companies gave sign-on bonuses to new graduates.

At Texas A&M University, Daniel T. Hanson, job coordinator for the chemical engineering department, also observed stiff competition for B.S. graduates. "I am fairly sure there are more jobs for B.S. chemical engineers than there are students available to fill them," he says. He believes the major reason for the high demand is the short-

Help-wanted ads have declined since last winter



a Column-inches published during consecutive periods of four weeks each; no issues were published in last week of December 1986, 1987, and 1988.

age of B.S. candidates. In 1989, Texas A&M had the lowest number of B.S. graduates since 1966. However, the freshmen class this year is larger. "I suspect this is partly due to the excellent offers at entry levels," he explains. As a consequence of high demand, some chemical and petroleum firms are giving sign-on bonuses, Hanson says.

Ronald Darby, professor in the chemical engineering department at Texas A&M, believes that one reason for the strong demand this year is the large number of jobs being offered by companies that design and build chemical plants.

Most industry spokesmen say that they hired more chemical professionals at all degree levels this year than in 1988, mostly because of expansions in plant capacity and in research.

Dausses of Phillips Petroleum says his company hired "10% more chemical professionals across the board" in part because of plant modifications and expansions Phillips has under way. Dausses believes that one explanation for the strong demand for B.S. chemists may be the shortage of chemical engineers. In some cases, "recruiters were trying to fill those positions with chemists," he explains.

He calls the strong 5 to 10% increase in starting salaries "really surprising." It is causing what he terms a "compression" problem—salaries for new hires "start dominoes moving up the organizational ladder, forcing companies to consider adjusting salaries of workers already on the payroll."

Robert K. Armstrong, manager of professional staffing at Du Pont, reports that his company hired fewer Ph.D. chemists than it did the year before, about the same number of B.S. and M.S. chemical engineers, and more Ph.D. chemical engineers. However, he found the job market competitive for all these categories, but especially for B.S. and M.S. chemical engineers. As a result, there is more talk about bargaining for salaries this year, he says.

In contrast, job openings for chemical professionals at Dow Chemical are up substantially this year, says James E. Townsend, manager of recruiting programs. The number of B.S. chemists hired was up 20 to 25%, Ph.D. chemists up 100%, B.S. chemical engineers up 30%, and Ph.D. chemical engineers more than 100%. The new job opportunities at Dow arose mainly because of expansion in facilities and strong business conditions. "We're hearing a lot of rumors about signing bonuses and report-to-work allowances," Townsend says. "But we haven't heard anyone actually say they are giving bonuses."

Union Carbide also has had an increased need for chemical professionals this past year. According to Thomas J. Neelen, manager of professional staffing, about 15 to 20% more B.S. and M.S. chemical engineers were hired, primarily because Carbide is expanding facilities around the country. "We filled the majority of our openings, but recruiting would have been considerably easier if the supply had been greater and there hadn't been so many other companies looking for so many B.S. chemical engineers."

Even though Procter & Gamble hired fewer chemical engineers this past year, P&G's Schulz found competition intense. "Unless we have a recession, we could easily be moving into a tight scene—not necessarily a panic scene, but a tight scene," he comments.

College placement personnel, department heads, and industrial recruiters believe that demand for chemical professionals next year will be just as high or even higher. Most add that a recession could change the situation markedly, but they don't expect an economic downturn.

The University of California's Miller thinks that, barring a recession, demand for B.S. and Ph.D. chemists will remain strong. Aylesworth of the University of Wisconsin also thinks the job market for chemists next year will be about the same as it was this year. Already the schedule of companies who have signed up to interview students is fairly full, she says.

Simon of the University of Illinois says, "We're going to have a full house this fall. It looks terrific. I expect hiring will be up this year, especially for B.S. chemical engineers."

Industry spokesmen express concern about finding enough candidates of the caliber they want. Carbide's Neelen expects the job market next year will be "just as competitive. Recruiting will be at the same level, if not greater, and shortages will still exist, particularly in chemical engineering."

Dausses of Phillips Petroleum expects that the market for chemists and chemical engineers "will be very hot." Demand at his company will be up another 10% and the number of graduates will be down, he says. Dow Chemical's Townsend expects that demand will be "at least as good as in 1989, if not a little bit better. I expect to see pressure and competition next year for chemical engineers." Schulz of Procter & Gamble expects that the job market for chemical engineers will be "tighter this coming year than it was last year. I think that some companies that don't have salary or location advantages will not find satisfaction. As a consequence, they are going to either go with a chemical engineering graduate who is not as strong as they want, or go with a substitute degree, or they're going to pay extra money."

Overall demand for chemists, as shown in the column-inches of help-wanted ads in C&EN, was slightly higher in the past 12 months than it was in the previous 12 months. However, in 1989, the volume of advertising did not reach the peak that it attained in September 1988.

Unemployment figures for chemists who are members of ACS are at historically low levels. As of March 1989, the overall unemployment rate was 1.0%, the same as it was in March 1988. The rates for all categories, whether minority or nonminority, male or female, at all degree levels are close to 1%, about as low as they have ever been since ACS initiated employment surveys in 1971.

The ACS starting salary survey also compiles unemployment rates for newly graduated chemists and chemical engineers as of last June. These data, too, reflect high demand. For Ph.D. chemists, the unemployment rate dropped from 11% in 1988 to 6%. For chemical engineers with a bachelor's degree, the rate fell from 8% to 7%. □

Salaries

For newly graduated chemists and chemical engineers, starting salaries are higher at all degree levels

Starting salaries followed the same trend as demand for chemical professionals this year. They are up for both chemists and chemical engineers at all degree levels, but did not rise as much as might be expected from the increased demand.

According to a recent ACS survey, the median salary of inexperienced M.S. chemists changed the most. It jumped 13% from $27,700 in 1988 to $31,200 this year. (However, last year's median had been essentially unchanged from the year before, while those for both B.S. and Ph.D. graduates were higher.) The median salary for B.S. chemists went up 6% from $21,900 to $23,200, but for Ph.D. chemists, it rose only 4% from $40,500 to $42,000.

The changes in chemists' starting salaries over the past year are consistent only with what has happened over the past decade for chemists with a bachelor's degree. Salaries for inexperienced B.S. chemists advanced at an average rate of about 5% per year between 1979 and 1989, almost the same as the change between last year and this year. In contrast, starting salaries for both M.S. and Ph.D. graduates increased about 6% per year over the past decade, very different from the 13% and 4% changes that occurred this year.

When adjusted for the 5% inflation rate, the median starting salary for M.S. chemists still took a large jump, 8% over that in 1988. The median for B.S. chemists, however, rose only 1% and that for Ph.D. chemists declined 1%. Since 1979, the changes in starting salaries after adjustment for inflation have been mixed. The median starting salary for B.S. chemists has declined 4%, the median for M.S. chemists has increased 10%, and that for Ph.D. chemists has risen 9%.

For more than a decade, starting salaries for chemical engineers with a bachelor's degree have been much higher than salaries for inexperienced B.S. chemists. The difference this year is 43%, the same as it was in 1988.

Unlike last year, when starting salaries of chemical engineers at all degree levels did not even advance enough to keep up with inflation, the median salary of B.S. chemical engineers increased 6% to $33,000, the salary for chemical engineers with a master's degree rose 9% to $36,000, and that for engineers with a Ph.D. degree climbed 6% to $47,000.

These data were collected by the ACS Market & Business Analysis Department from 3500 respondents to a survey of chemistry and chemical engineering graduates. However, because salaries at most degree levels escalated markedly over the course of the school year (about $2000 to $3000, according to anecdotal information), the results of the survey, which are medians for the entire school year, are probably lower than the medians for only those students hired late in the school year—in June, July, and August, for example. Last year salaries were more stable over the course of the school year. Therefore, the percentage changes from last year to late summer this year may actually be greater than the ACS survey indicates.

In the late 1970s and early 1980s, inexperienced women chemists earned more than their male counterparts. In 1983, the situation reversed and median starting salaries for male chemists became greater again. This year the salary differences changed again. At the B.S. level, women earn $24,000 at the median, 4% more than men. However, at the M.S. and Ph.D. levels, men continue to earn more than women. Men with a master's degree earn $32,000, 23% more than women, whereas men with a Ph.D. degree earn $42,000, only 1% more.

Inexperienced male chemical engineers with a bachelor's degree earn $33,000 at the median, 1% more than comparable women. At the M.S. and Ph.D. levels the number of women who responded to the survey is so small that significant comparisons cannot be made.

In private industry, the starting salaries for male chemists at the M.S. and Ph.D. levels are higher than those for comparable women, but at the B.S. level the median starting salary for men is lower than that for women. B.S. women graduates started with a salary of $26,000, 8% higher than the $24,000 for men. Men chemists with a master's degree earn $32,000, 7% more than the salary for women. At the Ph.D. level, the median starting salary for

men at $43,650 is 4% more than the $42,000 for women.

As usual, inexperienced chemists who choose to work in private industry earn more than they do in almost any other sector. For example, inexperienced Ph.D. chemists earn a median salary of $42,950 in industry, whereas those employed by a college or university earn only $27,000. Inexperienced chemical engineers also seem to have higher median salaries in private industry than they have in other sectors, but the number in other sectors who responded to the survey is too small to be significant.

Of those chemists who graduated with a bachelor's degree, about 52% plan to pursue advanced full-time studies in the fall of 1989. In contrast, only 20% of the B.S. chemical engineering graduates intend to study full-time in the fall.

Of those B.S. graduates in chemistry who plan to pursue full-time advanced studies in the fall of 1989, 39% will study chemistry and an almost equal number, 32%, will study medicine. Other fields that B.S. chemists have chosen for advanced study include biochemistry (9%), dentistry (3%), pharmacy (3%), and chemical and biochemical engineering (1%). In contrast, almost three quarters (71%) of the B.S. chemical engineering graduates who plan to pursue advanced full-time studies will be taking courses in chemical or biochemical engineering. Medicine, at 7%, is the B.S. chemical engineers' second highest choice and other engineering, at 6%, the third. Undergraduate work in chemistry is used much more than chemical engineering as a stepping stone to careers in other fields.

In contrast to salaries of inexperienced professionals, the salaries of more experienced chemical professionals advanced only moderately this year. According to a survey of about 12,000 ACS members completed in March, median base salaries for chemists, at all degree levels, are only 5% higher than they were last year. This advance was just enough to keep up with inflation, which was 5% from March 1988 to March 1989. These changes in salaries are almost the same as those that occurred last year, when the median salary of B.S. chemists rose 6%, and those for M.S. and Ph.D. chemists both rose 5%.

Similarly, during the past decade salaries of chemists at all three degree levels have remained fairly constant when adjusted for inflation. The median salary of B.S. chemists has declined slightly, and the medians for M.S. and Ph.D. chemists have increased only slightly.

In contrast to the salaries of inexperienced chemical engineers, the median salaries of more experienced chemical engineers in industry remained fairly flat. For Ph.D. chemical engineers in industry, the median was $64,700 compared with $62,900 last year (up 3%). Chemical engineers with a master's degree earned a median salary of $53,000 compared with $50,900 last year (up 4%), and B.S. chemical engineers earned a median salary of $47,700 both this year and last. None of these salaries advanced enough to keep up with inflation.

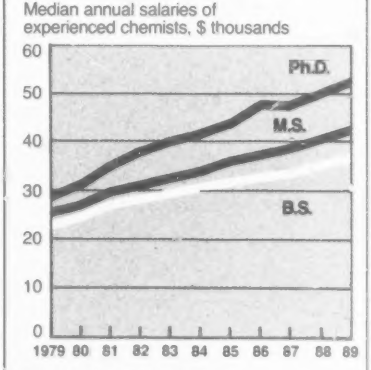
The gap between salaries for men and women chemists remains about the same as it has been for the past few years. When women's salaries are adjusted for the differences in average length of experience between them and men, the mean (rather than the median) salary for Ph.D. women chemists in industry is only 87% of the mean for men. In academia, women earn 17% less than men. At the B.S. level, the differences are even greater. In industry, women chemists with a B.S. degree earn 15% less than comparable men chemists.

One reason women's salaries are lower than men's is that women are much less likely than men to hold supervisory positions. Therefore, when the salaries of those chemists who earned their B.S. degrees less than 10 years ago are compared, the salary differences are much smaller because relatively few chemists hold a supervisory position after only a few years of work. For Ph.D. chemists in industry who earned their B.S. degree less than 10 years ago, the median salary for women, $45,000, is almost identical to that for men, $44,800.

For Ph.D. chemists, overall salaries in industry remain higher than those in academia. In private industry, the median salary is $58,000 compared with $43,000 in academia. But the median salary of Ph.D. chemists working for Ph.D.-granting schools is $54,900, much higher than the overall median for academia.

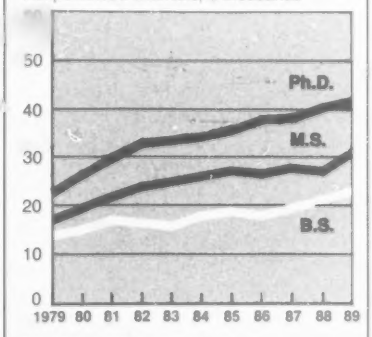
Industrial chemists' salaries vary greatly depending on the industry. Ph.D. chemists who work in the petroleum and natural gas industry have the highest mean salary, $69,500; the next highest mean salary is in the pharmaceutical industry, $64,900. B.S. chemists in the basic chemicals, plastics, and electronics industries have the highest mean salaries, about $46,200. (These means have been adjusted for differences in average length of experience of chemists for each group.) □

Salaries of experienced chemists rise steadily...



Note: Data as of March of each year.
Source: ACS annual surveys

...while those for new chemists also are higher



Note: Data as of the summer of each year.
Source: ACS annual surveys

Data corrected for CPT annual report

Owing to an anomaly in the computer program, most of the totals for bachelors, masters, and doctorates in chemistry and chemical engineering are incorrect in the tables accompanying the ACS Committee on Professional Training 1988 annual report (C&EN, June 19, page 93). Totals of the individual schools are correct, but the grand totals in many instances are incorrect. The corrected tables appear below.

Corrected reprints of the 1988 CPT Annual Report are available from the Office of Professional Training, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

Summary of data from approved schools, 1984–88

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1984	577	9819	4201	5618	321	1637	189	1777
1985	579	9679	4021	5658	316	1621	186	1806
1986	580	9295	3892	5403	315	1620	187	1885
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8372	3453	4919	319	1584	192	1955
CHEMICAL ENGINEERING[a]								
1984	120	6866	6866	—	114	1436	101	357
1985	123	6442	6442	—	118	1489	104	418
1986	118	5229	5229	—	116	1244	103	460
1987	107	4435	4435	—	103	1078	90	533
1988	128	3524	3524	—	124	1036	106	603

a Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Summary of totals from 1988 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	584	5077	3295	8372
Certified		2116	1337	3453
Noncertified		2961	1958	4919
Masters	319	1054	530	1584
Doctorates	192	1504	451	1955
CHEMICAL ENGINEERING				
Bachelors,				
Certified	128	2612	912	3524
Masters	124	850	186	1036
Doctorates	106	526	77	603

More tours information for PACIFICHEM '89

The following list of tours planned for Wednesday, Thursday, and Friday at PACIFICHEM '89 in Honolulu, Dec. 17–22, was inadvertently omitted from the Final Program of the meeting, Oct. 2 issue of C&EN:

WEDNESDAY, DEC. 20

GP-18. 8 AM to 5 PM. Special Tour: Share the Tradition. See GP-8 for details. Cost: $53. Minimum 20.

GP-19. 8:30 AM to 12:30 PM. Special Tour: a Monarchy Day Revisited. See GP-2 for details. Cost: $17. Minimum 30.

GP-20. 8:30 AM to 12:30 PM. Special Tour: a Camera Buff's Historical Tour. See GP-3 for details. Cost: $16. Minimum 30.

GP-21. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.

GP-22/adult; GP-22c/child. 12:25 to 10:30 PM. Polynesian Cultural Center Tour. See GP-12 for details. Cost: $49 adult; $25 child. Limit 100.

GP-23/adult; GP-23c/child. 1:15 to 5:45 PM. Mini Circle Island/Sea Life Park Tour. See GP-7 for details. Cost: $27 adult; $23 child. Limit 100.

THURSDAY, DEC. 21

GP-24/adult; GP-24c/child. 6:16 AM to 7:30 PM. One-Day Tour to Maui. Fly to Kahului, then drive to the top of the Haleakala Crater, 10,000 feet above sea level. See rare silversword and the state bird nene. Continue to Iao Valley and Old Lahaina Town, once the capitol of Hawaii's kingdom. Stop for lunch (cost not included). Price does include round-trip transfers in Honolulu, airfare, and admissions to Haleakala National Park, and tour on Maui. Cost: $120 adult; $99 child. Limit 50. *Advance registration required.*

GP-25. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.

GP-26/adult; GP-26c/child. 8:45 AM to 12:30 PM. Arizona Memorial Excursion. See GP-4 for details. Cost: $13 adult; $10 child. Limit 100.

GP-27/adult; GP-27c/child. 1 to 5 PM. Scenic Honolulu City/Dole Pineapple Cannery Tour. See GP-17 for details. Cost: $16 adult; $12 child. Limit 100.

FRIDAY, DEC. 22

GP-28. 8 AM to 5 PM. Special Tour: Share the Tradition. See GP-8 for details. Cost: $53. Minimum 20.

GP-29. 8:30 AM to 12:30 PM. Special Tour: a Camera Buff's Historical Tour. See GP-3 for details. Cost: $16. Minimum 30.

GP-30. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.